

The Increase in Efficiency of the Modes Power Resources Consumptions of the Processing Equipment of the Enterprises of Oil-processing Industry

Dmytro Shokarov, Oleksandr Lazurenko,
Halyna Cherkashyna
National Technical University «Kharkiv Polytechnic
Institute»
Kharkiv, Ukraine
email: shokareff@gmail.com

Viktorija Chorna,
Kremenchuk Mykhailo Ostrohradskyi National University
Kremenchuk, Ukraine
email: chornajav@gmail.com,

Abstract — The technique of static planning of an experiment for creation of mathematical model of energy consumption of technological plants of the enterprise of oil industry is offered that has allowed to analyze effectively the factors which influence the production and to optimize the expenses, to reduce the prime cost and to increase the overall performance of the enterprise in general. **Bibl. 11, Fig. 4.**

Keywords – *planning of an experiment, energy consumption optimization, oil-processing industry, energy resources.*

I. INTRODUCTION

One of the most important tasks of any industrial enterprise is cost cutting on the energy resources consumed in the course of work. First of all it is connected with the constant price increase and the tariffs for energy carriers. The high cost of energy resources at their irrational use increases the prime cost and leads to the decrease in the competitiveness of the production.

The impact on the level of energy consumption of the oil processing installations is exerted by the degree of their load. So, the plants of the foreign oil processing enterprises are loaded for 80–85% while Ukrainian – only for 40% [1]. Certainly, it affects the size of the cost of the energy resources.

The relevance of the research. The analysis of energy consumption has allowed to establish by the Ukrainian and foreign oil processing plants that the specific expenses of energy resources at the Ukrainian enterprises exceed specific indicators of foreign installations by 1,5–3 times [1,3]. The improvement of these indicators demands technical re-equipment of the oil processing enterprises of Ukraine that is accompanied by considerable capital investments. Therefore, the search of the opportunities of the optimization of expenses of energy resources depending on the conditions and the volumes of the processing and industrial production is the major technical and economic task.

The purpose of the research. The development of a mathematical model of optimum consumption of energy resources of the most power-intensive consumers of oil-

processing industry on the basis of a method of planning of an experiment.

II. THEORETICAL RESEARCH

The processing industry is a kind of difficult production and is characterized by complex and continuous processes of processing of raw materials, big material capacity and power consumption of technological processes, high extent of automation of production. The basis of all oil refineries is made by technological installations of distillation of oil. Their main purpose consists of division of oil into fractions and further processing or their use as components of commodity oil products [2]. The range and quality of the received components and also technical and economic indicators of further processes of processing of oil products depends on the efficiency of functioning of plants of distillation.

In the course of the processing of oil products technological plants consume different types of energy resources: electric and thermal energy, fuel, gas, water or steam.

It should be noted that in the general expenses of the oil processing enterprise the cost of the thermal energy is about 55%, electric energy – about 40% and the cost of other resources is only about 5% [1, 3].

In view of the complexity of technological plants the most power-intensive part of production – the combined GK-3/1 installation consuming 34% of total amount of energy resources of the enterprise and producing 26% of total amount of production is subject of the analysis in this article. The plant consists of the block of the catalytic cracking (CC) which is responsible for deep processing of any oil fractions, the block of atmospheric distillation of oil (AD) and the electrodesalinating (EDS) [2] setting. The production capacity of blocks of catalytic cracking and atmospheric distillation of oil is in the equal volume of 46,5% and the block of an desalination and dehydration – 7%. Comparing these data with the blocks given on energy consumption by the combined plants presented in fig. 1 it is possible to draw a conclusion that the most part of energy resources is consumed by the block of catalytic cracking while the EDS block consumes

insignificant volumes of electric and thermal energy, without consuming fuel.

For the purpose of the identification of communications and dependences between the volume of the production and the consumption of energy resources the complex of further research is necessary. The comparative analysis of the existing methods has allowed to choose the method of planning of an experiment [6, 7].

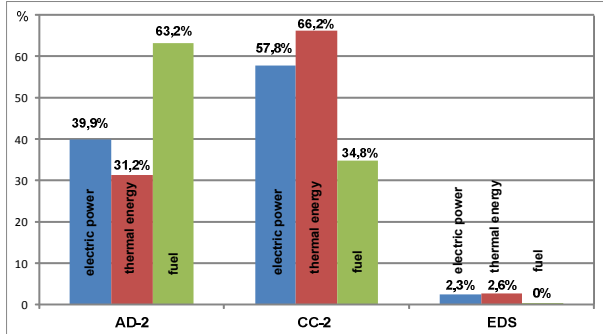


Fig. 1. The balance of the energy consumption by installation blocks GK-3/1

The planning of an experiment consists of the development of recommendations on the basis of a research of preliminary skilled data for their further realization and the creation of mathematical model of the studied process for the purpose of further forecasting of production [4, 5]. As a rule, the results of such researches are the development of the most optimum recommendations, technological process having important economic, technical, technological consequences and involving the modernization of both the separate technological process and the whole production.

The analyzing schedules of energy consumption from fig. 2-4, it is visible that for 2 months in 2015 (the stroke line) and 2016 (the continuous line) the plants did not use the energy resources which is connected with the planned repair works.

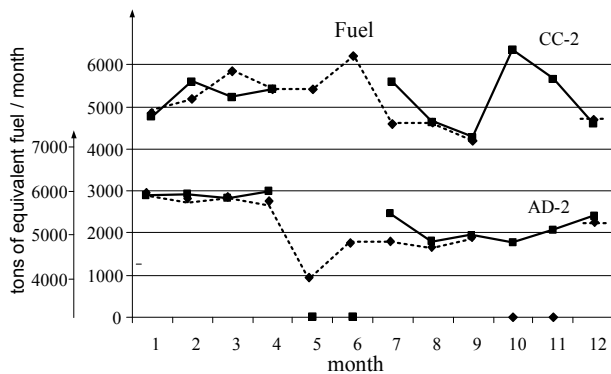


Fig. 2. The data of consumption of fuel CC-2 and AD-2 plants

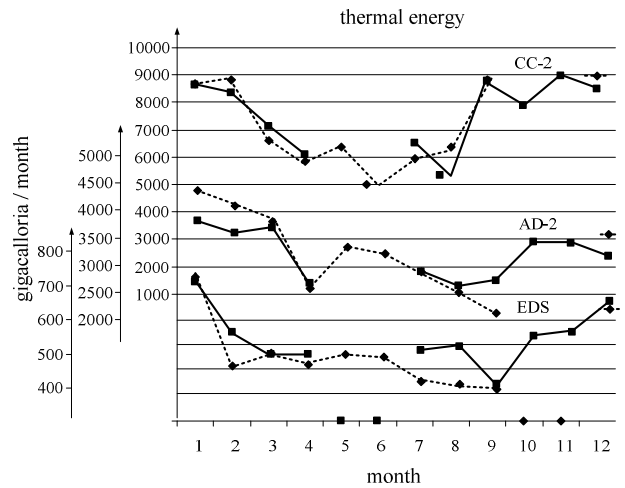


Fig. 3. The data of the consumption of the thermal energy CC-2, AD-2 and EDS-2 plants

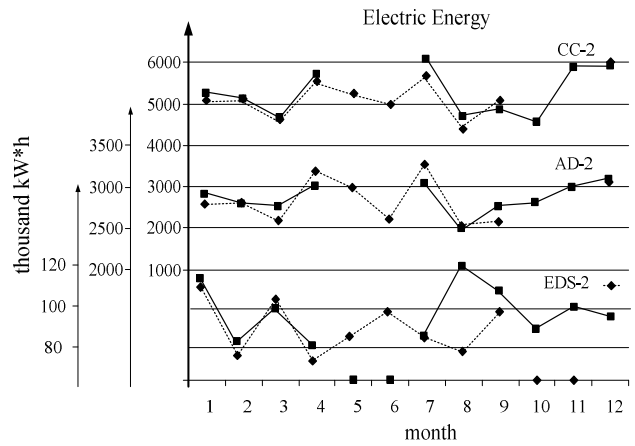


Fig. 4. The data of the consumption of the electric energy CC-2, AD-2 and EDS-2 plants

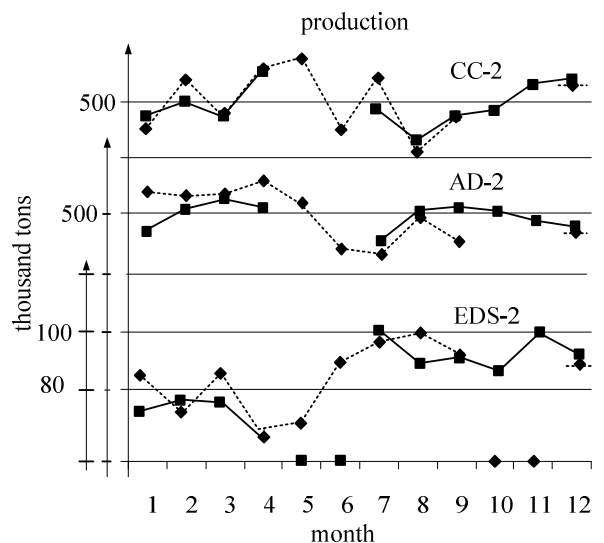


Fig. 5. The production volume CC-2, AD-2 and EDS-2 plants

III. CALCULATION RESULTS

Proceeding from it for the further research four months are not taken into account. When carrying out an experiment two parameters are taken as a basis p^{\min} – the minimum quantity of experiments and respectively the maximum quantity p^{\max} . The experiment matrix $N = p^k = 2^3 = 8$, (for experiments 1 and 2),

$N = p^k = 2^2 = 4$ (for an experiment 3), k – is as a result defined. For three experiments of CC-2, AD-2, EDS-2 the matrix presented in the form by tab. 1 is planned respectively. In the table the data on energy consumption are entered by the plants in conventional units, i.e. deviations from an average value of energy consumption and production (fig. 2-5) are specified.

TABLE I. MATRIX OF EXPERIMENT

№ Exp.	Coding of factors			Experiment 1(y1)			Experiment 2 (y2)			Average value (\bar{y})		
				CC-2	AD-2	EDS-2	CC-2	AD-2	EDS-2	CC-2	AD-2	EDS-2
	x_1	x_2	x_3									
1	+	+	+	1.59597	1.3049	1.3753	1.54622	1.3046	1.32141	1.57109	1.30475	1.34835
2	-	+	+	0.82321	0.7916	0.95143	0.81621	0.8159	0.94142	0.81971	0.80375	0.94642
3	+	-	+	1.01983	0.7289	1.13211	0.94214	0.7320	1.19311	0.98099	0.73045	1.16261
4	-	-	+	0.98631	0.81312	0.79314	0.97216	0.8522	0.79151	0.97923	0.83268	0.79232
5	+	+	-	1.18532	0.90908	-	1.19204	0.92803	-	1.18868	0.91855	-
6	-	+	-	0.98118	0.8787	-	0.99173	0.7955	-	0.98646	0.8371	-
7	+	-	-	0.99631	0.8180	-	0.98041	0.8449	-	0.98836	0.83145	-
8	-	-	-	0.65141	0.5231	-	0.69131	0.57925	-	0.67136	0.55117	-

In the table the following designations are accepted: $x1$ – the electric power, $x2$ – heat, $x3$ – fuel, $y1$ – production (2015), $y2$ – production (2016). When carrying out a factorial experiment the scheme with the identical number of repeated experiments is used. These additional experiments allow to estimate the dispersion of single measurement S_{sm}^2 :

$$S_{sm}^2 = \frac{\sum_{i=1}^N \sum_{u=1}^m (y_{iu} - \bar{y}_i)^2}{N(m-1)} = \frac{\sum_{i=1}^N S_i^2}{N} \quad (1)$$

The average value between experiments \bar{y} :

$$\bar{y}_i = \frac{\sum_{u=1}^m y_{iu}}{m} \quad (2)$$

where $i=1..N$ – the line number of a matrix of planning; $u=1..m$ – the number of repeated experiments; S_i^2 – the dispersion of a deviation of repeated experiments in each point of the plan from the average value of a response in this point; y – the matrix $N \times m$ of responses; the number of degrees of freedom S_{sm}^2 is equal $f_2 = N(m-1)$.

Results of calculations are presented in tab. 2.

TABLE II. THE RESULTS OF CALCULATIONS

№	Average Value \bar{y}			Dispersion S^2			Actual value of function \hat{y}			$\sum_i (\bar{y}_i - \hat{y}_i)^2$		
	CC-2	AD-2	EDS-2	CC-2	AD-2	EDS-2	CC-2	AD-2	EDS	CC-2	AD-2	EDS-2
1	1.5711	1.3047	1.3483	0,0012	0,00005	0,0014	1.5709	1.2998	1.3098	0	0,00002	0.0014
2	0.8197	0.8037	0.9464	0,00003	0,00029	0,0005	0.929	0.7201	0.9996	0,012	0,00699	0.0028
3	0.981	0.7304	1.1626	0,003	0,000004	0,0019	0.9307	0.7496	1.0683	0,0025	0,00036	0.0089
4	0.9792	0.8327	0.7923	0,0001	0,00076	0,0001	1.1088	0.9459	0.9233	0,0322	0,00128	0.0172
5	1.1887	0.9185	-	0,00003	0,000179	-	0.9795	0.8376	-	0,0438	0,00375	-
6	0.9864	0.7921	-	0,00006	0,00341	-	0.907	0.8533	-	0,0063	0,0037	-
7	0.9884	0.8314	-	0,00013	0,00036	-	1.0678	0.7702	-	0,0063	0,0001	-
8	0.6714	0.5512	-	0,0008	0,00157	-	0.6419	0.5883	-			-
Σ				0,00538	0,00645	0,0034				0.1040	0.0293	0.0308

When carrying out an experiment it is necessary that the results of measurements in each experience have been received with the maximum accuracy [7,8,9]. The check of a hypothesis of uniformity of dispersions is carried out by Kohhren's criterion [6]:

$$G_{\max} = \frac{S_{\max}^2}{\sum_{i=1}^N S_i^2} \quad (3)$$

For the first experience (CC-2 setting) $G_{\max 1} = 0,5608$, for the second (setting AG-2)

$G_{\max 2} = 0,5208$ for the third (setting EDS-2) $G_{\max 3} = 0,553$ The tabular value of Kokhren's criterion at the quantity of degrees of freedom $f_1 = k-1=1$ and $f_2 = N=8$ equal $G_{tab} = 0,6798$ with $f_1 = k-1=1$ and $f_2 = N=4$ $G_{tab} = 0,9065$. In case when $G_{\max} < G_{tab}$ in all experiments, it is possible to say that the experiment is executed with the statically identical accuracy.

For the assessment of the influence of the specified factors and the mathematical description of the process the model of the first order is used:

$$y = a_0 + a_1 \cdot x_1 + a_2 \cdot x_2 + a_3 \cdot x_3 + a_{12} \cdot x_1 \cdot x_2 + a_{13} \cdot x_1 \cdot x_3 + a_{23} \cdot x_2 \cdot x_3 + a_{123} \cdot x_1 \cdot x_2 \cdot x_3. \quad (4)$$

The free term of the equation of regression is

defined as $a_0 = \frac{\sum_{i=1}^N \bar{y}_i}{N}$.

The regression of the coefficients characterizing influence of factors:

$$a_{ij} = \frac{\sum_{i,j=1}^N x_{ik} \cdot x_{jk} \cdot \bar{y}_i}{N} \quad (5)$$

After the calculation of all coefficients of the equation (4) take the following form:

1) the equation for CC-2 is:

$$y_1 = 0.92323 + 0.1588 \cdot x_1 + 0.1182 \cdot x_2 + 0.06452 \cdot x_3 + 0.0793 \cdot x_1 \cdot x_2 + 0.02923 \cdot x_1 \cdot x_3 - 0.0106 \cdot x_2 \cdot x_3 + 0.10805 \cdot x_1 \cdot x_2 \cdot x_3.$$

2) the equation for AD-2 is:

$$y_2 = 0.85123 + 0.095799 \cdot x_1 + 0.1148 \cdot x_2 + 0.0666 \cdot x_3 + 0.0505 \cdot x_1 \cdot x_2 + 0.04623 \cdot x_1 \cdot x_3 + 0.002154 \cdot x_2 \cdot x_3 + 0.10025 \cdot x_1 \cdot x_2 \cdot x_3.$$

3) the equation for EDS-2 is:

$$y_3 = 0.96242 + 0.193053 \cdot x_1 + 0.08498 \cdot x_2 + 0.0079 \cdot x_1 \cdot x_2.$$

The values of the coefficients of regression a_0 and a_{ji} also allow to estimate the extent of influence of factors and their interactions on optimization parameter. The more the numerical value of coefficient, the greater influence is exerted by the factor. If the coefficient has the sign "+", then with increase in value of a factor the parameter of optimization increases and if "-" – decreases. The size of the coefficient corresponds to the contribution of this factor to the optimization parameter size upon the transition of value of the factor from zero level on top or lower.

The Check of adequacy of models is carried out by the means of Fischer's criterion [6]. Further an inspection

of a hypothesis of adequacy of model is carried out and, at last, for each calculated coefficient b_j it is possible to check its importance according to t - Student's criterion [6]. This set of criteria allows to estimate the reliability of the received results of an experiment rather fully.

The dispersion of the adequacy is defined proceeding from the equation:

The dispersion of the adequacy is defined proceeding from the equation:

$$S_{ad}^2 = \frac{1}{N-g} \sum_{i=1}^N r_i (\bar{y} - \tilde{y}_i)^2, \quad (6)$$

where r_i – the number of parallel experiments in i - line of matrix line of planning; \bar{y} – an arithmetic average of function r_i of a response from parallel experiments; \tilde{y} – the value of function of a response predicted on the equation in i - experiment; g – the number of significant coefficients in the regression equation; N – the number of independent experiments.

The value of Fischer criterion (the dispersive relation) is defined by F from the equation:

$$F = \frac{S_{ad}^2}{S_{sm}^2}. \quad (7)$$

The tabular value of Fischer criterion at a number of degrees of freedom $f_1 = k-1=1$ и $f_2 = N=8$ equals $F_{tab} = 5,318$, with $f_1 = k-1=1$ and $f_2 = N=4$ – $F_{ma6} = 7,709$ [6].

For the first experiment (plant CC-2) $F_1 = 4,296$, for the second – (plant AD-2) $F_2 = 4,821$, for the third – (plant EDP-2) $F_3 = 5,531$.

Fulfilling condition $F > F_{tab}$ demonstrates that the mathematical model is adequate to the studied process.

The schedules of the received surface of response [10] submitted in fig. 6 and 7, determined by the equation $y1, y2, y3$ are of a special interest for the analysis of the received results of modelling. On each of three schedules the absent factor is recorded at the main level (0.0).

As it can be seen from the figure for the plant CC-2 the growth of value of volume of production of Y substantially depends on the electric energy of X1 and heat of X2 in smaller – from X3 fuel and an optimum ratio of factors of X1 and X2 in a smaller measure of X1 and X3. Besides, Y has an optimum value of about a point (-0.1, 0, 0.3). For the plant AD-2 the value of production substantially depends both on electric energy and on thermal, and the optimum value is about a point (-0.2, 0, 0.2).

$$y_1 = 0.92323 + 0.1588 \cdot x_1 + 0.1182 \cdot x_2 + 0.06452 \cdot x_3 + 0.0793 \cdot x_1 \cdot x_2 + 0.02923 \cdot x_1 \cdot x_3 - 0.0106 \cdot x_2 \cdot x_3 + 0.10805 \cdot x_1 \cdot x_2 \cdot x_3$$

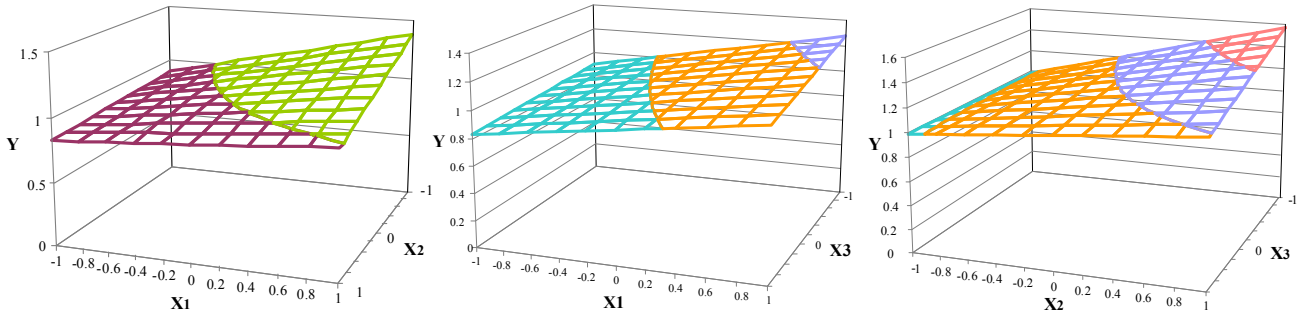


Fig. 6. The surface of a response of factors of planning of an experiment of plant CC-2

$$y_2 = 0.85123 + 0.095799 \cdot x_1 + 0.1148 \cdot x_2 + 0.0666 \cdot x_3 + 0.0505 \cdot x_1 \cdot x_2 + 0.04623 \cdot x_1 \cdot x_3 + 0.002154 \cdot x_2 \cdot x_3 + 0.10025 \cdot x_1 \cdot x_2 \cdot x_3$$

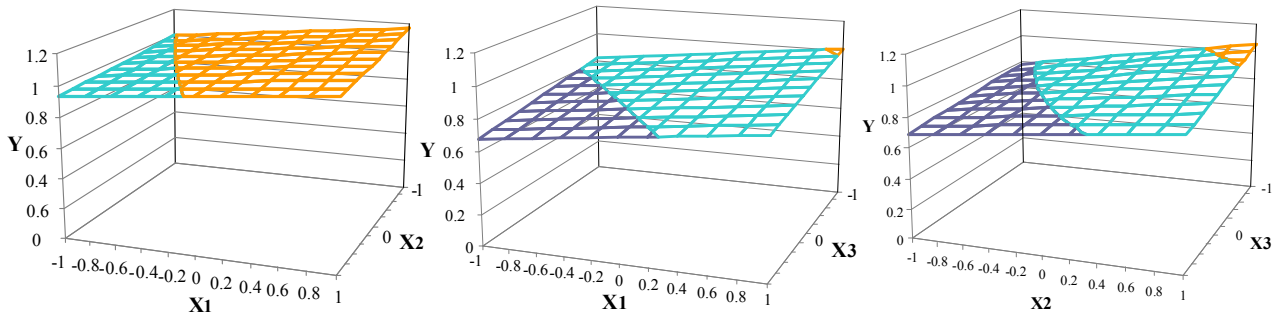


Fig. 7. The surface of a response of factors of planning of an experiment of plant AD-2

III. CONCLUSIONS

The received mathematical models of an energy and resource consumption of plants allow to optimize the modes of their work due to the increase in the energy efficiency of technological processes.

The results of a research demonstrate the influence of the factors of an experiment on the general production that indicates the increase of potential system effectiveness electro and heat supplies of the plant. According to the preliminary estimates [11], an irrational use of energy resources in plants can lead to their overexpenditure for 3%-7% and to decrease in production on 1,2 ... 1,5%.

The existence of quantitative estimates of the influence of earlier unaccounted factors will allow to lower significantly an error in the existing technique of the consumption of the resources. The offered approach can be successfully used for specification of the most optimum recommendations on loadings of the equipment for the purpose of improvement of technological process.

REFERENCE

- [1] Malyarenko O.E. Energetichna efektyvnist modernizatsiyi ta rekonstruktsiyi naftopererobnoyi promyslovosti Ukrainy, // Problemi zagalnoyi energetiki -- 2006. - № 14. - p. 85-90
- [2] Skoblo A.I., Molokanov Yu.K., Vladimirov A.I., Schelkunov V.A. Protsepy i apparaty neftepererobki i neftehimii: Uchebnik dlya vuzov. - 3-e izd. - M.: OOO "Nedra-Biznesstse"nt", 2000. - 677 p.
- [3] Chorna V.O. Opis zahodiv energoresursozberezhennya dlya

pidpriemstva naftopererobnoyi promyslovosti // Energozberezhennya na zaliznichnomu transporti ta v promyslovosti. Materiali 6 Mizhnarodnoyi nauko-vo-praktichnoyi konferentsiyi. 10-13 chervnya 2015 r. - Volovets: D.: DNUZT, 2015. P. 17-18.

[4] Rozen V.P., Shokarov D.A., Lyapota K.P. Pobudova prognoznoyi modeli energovitrat za dopomogoyu zastosuvannya metodu planuvannya eksperimentu // Visnik Natsionalnogo tekhichnogo unIversitetu «Harkivskiy politehichnyi Institut». Zbirka naukovih prats «Problemi avtomatizovanogo elektroprivodu. Teoriya y praktika» - Kharkiv - #28 - 2010 - P.220 - 223.

[5] Shokarov D.A., Lyapota K.P. Zastosuvannya metodu planuvannya eksperimentu dlya pobudovi modell, scho prognozuE obsyagi vipusku produktsiyi v zalezhnosti vid pokaznikiv energospozhivannya / // Elektromehanichni I energozberlGayuchI sistemi. Shchokvartalnyi nauko-vo-virobnichiy zhurnal. - Kremenchuk: KDPU, 2009. - Vip. 3/2009 (7). - P.57-60.

[6] Adler Yu.P. Planirovanie eksperimenta pri poiske optimalnykh uslovii // Yu.P. Adler, E.V. Markova, Yu.V. Granovskiy. - M.: Nauka, 1976.

[7] Cox, D. R. The theory of the design of experiments / D. R. Cox, N. Reid. CHAPMAN & HALL/CRC: Boca Raton London New York Washington, D.C., 2001. - 314 p.

[8] Planning for the unexpected, Scientific Computing World: February/ March 2006,

[9] Mahnaz Malekzadeh, Iain Bate, Sasikumar Punnekkat, "Using Design of Experiments to Optimise a Decision of Sufficient Testing", 2015 41st Euromicro Conference on Software Engineering and Advanced Applications (SEAA), vol. 00, no. , pp. 53-60, 2015, doi:10.1109/SEAA.2015.79

[10] Kryuchkova O.A., Kryuchkov Yu.O., Tarantsev E.K. Issledovanie parametrov dlya funktsii otklika s ispol'zovaniem metoda planirovaniya eksperimenta. Sovremennyye informatsionnyye tekhnologii. 2007. № 5. S. 10-13.

[11] Hubin I. V., Yelysovetskiy O. O., Shokarov D. A. Analiz sistem elektropostachannia ta elektrospozhyvannia tekhnolohichnoi ustanovky L-35/11-300 PAT «UKRTATNAFTA» Elektromekhanichni i enerhozberihaiuchi systemy. Shchokvartalnyi nauko-vo-virobnichiy zhurnal. - Kremenchuk: KrNU, 2011. - Vyp. 4/2011 (16). - S.120-12